CHAPTER 7

Influence of Cultivation Practices on Arable Crop Diseases

Victor W. L. Jordan and Josephine A. Hutcheon

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7.1 INTRODUCTION

The disposal of straw or stubble by incorporation as opposed to burning results in changes in the physical, chemical, and biological condition of the soil and also has various effects on pests, diseases, and weeds through interactions with other components. Therefore, due consideration must be given to crop-management strategies for straw disposal and stubble management in the intercrop period between harvest and sowing and their influence on subsequent integrated crop protection. The plow has traditionally been used to loosen the soil and incorporate crop residues. Such complete inversion of crop residues has a considerable influence on mineralization of plant nutrients and leaves bare soil, which increases nitrogen volatilization to the atmosphere. It also affects the survival of beneficial invertebrates and of soilborne pests, pathogens, and weeds. In some soils, as a consequence of plowing, soil structure is frequently impaired through the development of a "plow pan." Minimum-tillage systems, which incorporate 70% of crop residues in the top soil layers and leave 30% on the soil surface, and direct drilling may affect the incidence of trashborne diseases and favor soil fauna, particularly predators of pests. Research into the long-term effects of alternative soil tillage systems, based on conditioning the soil and incorporating crop residues in one pass without inverting the soil, has shown differential effects on a range of important arable crop diseases. These effects may be largely dependent upon the inoculum source and transmission capabilities (Table 7.1) which, in turn, may have implications for crop protection.

7.2 TRASH-BORNE PATHOGENS

7.2.1 Eyespot (*Pseudocercosporella herpotrichoides/Tapesia yallundae*)[16]

The pathogen survives saprophytically on previously infected culms that remain on or in the soil surface from one year to the next, and survival is prolonged when straw decomposition is delayed. Primary infections develop from spores produced on and dispersed by rain splash up to 2 m from the source, from these infected culm bases. Although complete inversion of previous crop remains by plowing has been considered an effective option to reduce infection potential in successive cereal crops, reinverted partially decomposed straw from previous years' cultivation during seedbed preparation is still capable of producing viable spores. As a result, in wheat-dominated systems or where cereal crops are grown intensively, plowing will not

Table 7.1 Major Diseases of Wheat and Barley in the U.K. and Their Infection Source

Crop	Disease	Causal Organism	Source	Tissue Affected
Wheat	Leaf spot	*S. tritici*	Stubble	Leaf
	Glume blotch	*S. nodorum*	Stubble, seed	Leaf, stem,ear
	Eyespot	*P. herpotrichoides*	Stubble	Stem
	Sharp eyespot	*R. cerealis*	Stubble, soil	Stem
	Foot rot Ear blight	*Fusarium spp.*	Stubble, seed	Leaf, stem, ear
	Take-all	*G. graminis*	Soil-borne	Roots, stem
	Leaf stripe	*C. graminearum*	Stubble	Leaf, stem
	Tan spot	*P. tritici-repentis*	Stubble	Leaf
	BYDV	Aphid vector	Infected grass	Whole plant
	Mildew	*E. graminis*	Volunteers	Leaf, stem, ear
	Brown rust	*P. recondita*	Volunteers	Leaf, ear
	Yellow rust	*P. striiformis*	Volunteers	Leaf, ear
Barley	Leaf blotch	*R. secalis*	Stubble, seed	Leaf, ear
	Net blotch	*P. teres*	Stubble, seed	Leaf, ear
	Leaf stripe	*P. gramineum*	Seed	Leaf, ear
	Eyespot	*P. herpotrichoides*	Stubble	Stem
	Sharp eyespot	*R. cerealis*	Stubble, soil	Stem
	Take-all	*G. graminis*	Soil-borne	Roots, stem
	Fusarium	*Fusarium spp.*	Stubble, seed	Leaf, stem, ear

decrease eyespot inoculum as effectively as it will the inoculum of other trash-borne pathogens.

Infection potential of a field is thought to be a function of the quantity of infected culms on or in the soil surface. However, a very small amount of infective debris is sufficient to initiate infection. Quantitative studies have shown[6] that as little as one infected culm/10 m^2 can, under favorable weather conditions, initiate damaging levels of infection.

Monitoring inoculum release and infection in the U.K. showed that sporulation was abundant on infected crop debris over a wide temperature range (optimum ca. 5°C). In still air, splash-dispersed spores may be deposited within 1m of the inoculum source, but in wind, they can travel beyond 6 m. Although there were seasonal fluctuations in conidial production, sporulation usually began in October, peaked during December and January and, in most years, ceased by the end of March. Hence, eyespot epidemics are unlikely to be limited by inoculum shortage. Furthermore, infection could occur on 83% of the days when rain falls during this period annually. Thus, the infection processes from survival on straw, sporulation, dispersal, infection, and lesion development overlap during autumn and winter.

It was originally considered that the first cereal crop after a nonhost break crop is not at risk to eyespot, but reinversion of nondecomposed residues by deep cultivation (plowing) and the occurrence of the telomorph stage of the pathogen led to revision of this hypothesis.

The telomorph stage (*Tapesia yallundae*) has been recently observed,[4,10] with apothecia detected on leaf sheaths of culms in spring that release wind-borne ascospores, which have a greater dispersion capacity for more widespread and later infections.

From the point of view of sanitary measures and crop hygiene, soil cultivation by deep plowing after harvest was thought to be effective in lowering the infection

pressure, provided the infectious material does not reach the surface during seedbed preparation and sowing.

Although rapid decomposition of infected stubble is climatically dependent, it can be encouraged by shallow incorporation using soil-conservation-tillage techniques. Noninversion-tillage systems, for example, improve soil structure and the activity of soil biota, especially those microorganisms that enhance cellulytic breakdown and promote the decomposition process.

Soil cultivation should also be adapted, where possible, to the sequencing of host and nonhost crops. For example, it seems more appropriate to direct-drill a break crop, such as oilseed rape, after wheat and allow eyespot spores to discharge onto this nonhost crop, thereby exhausting the inoculum source. Alternatively, if the residues/infected culms of an eyespot-infected cereal crop have been deep-plowed after harvest, then shallow cultivation is more appropriate after the following harvest to avoid reinversion of nondecomposed infective crop residues.

Studies done on long-term continuous cereals experiments showed that significantly more eyespot-infected culms remained on or near the soil surface following direct drilling or noninversion tillage than after plowing. However, these different cultivation practices had no significant effect on disease incidence in autumn, or in the number of tillers infected at GSZ 31 (April) and at the end of the season GSZ 75 (July) (Table 7.2).[10] Similarly, extrapolation of data from 1094 winter cereal trials in Denmark between 1978 and 1986[15] showed no difference in eyespot incidence between plow and nonplow in April, but by July eyespot was significantly lower in nonplowed areas (Figure 7.1).

7.2.2 Wheat Leaf Stripe (*Cephalosporium graminearum*)

Wheat leaf stripe (*Cephalosporium graminearum)* is an important and locally destructive disease of winter wheat, especially in the wetter regions of Northern Europe, the United States, and Canada. The causal pathogen multiplies rapidly and sporulates profusely on straw residues on or in the soil surface under warm, damp conditions. It is also soil-borne, surviving on most dead and decaying plant material. The pathogen infects through the roots, more so where root systems have been damaged either naturally or by soil fauna,[12] and fungal threads penetrate the vascular system and block the water- and nutrient-conducting tissues. A toxin is also produced by the fungus, which appears to prevent chlorophyll formation in leaves and, thus,

Table 7.2 Effects of Straw Disposal and Tillage on Eyespot Infection of Winter Wheat in Continuous Cereal Systems in the U.K.

Straw Disposal	Cultivation Method	Infected culms/m^2	Infection Frequency*	Incidence* April–GSZ 31	Incidence* July-GSZ 75
Bale	Plow	18	68	87	73
Bale	Noninversion	117	66	85	53
Bale	Direct drill	431	66	96	45
Incorporate	Plow	23	71	91	62
Incorporate	Noninversion	83	69	90	60

Infection frequency and incidence expressed as a percentage.

Source: From Jordan, Hutcheon, and Kendall, 1997. With permission.

Table 7.3 Effect of Different Methods of Straw Disposal and Tillage on Incidence of Cephalosporium Leaf Stripe

Depth of tillage (cm)		1985 Burn	1985 Bale	1985 Chop Straw	1986 Burn	1986 Bale	1986 Chop Straw
0	(DD)	4.7	50.8	65.8	10.3	31.7	29.2
5	(P)	7.7	12.9	20.5	6.9	8.4	14.0
15	(P)	10.9	10.9	13.4	4.0	10.3	11.3
25	(P)	5.2	19.9	20.2	2.4	10.7	14.3
SED			6.18			4.22	

DD = direct drill; P = plow.

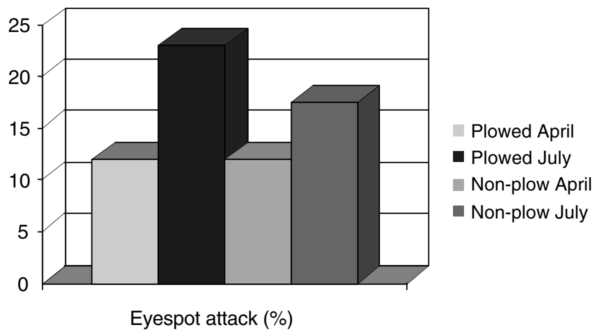

Figure 7.1 Adjusted mean attack (%) of eyespot in wheat and rye in April and July 1978–1986. (From Schultz, et al. With permission.)

induces yellowing, causing the typical leaf stripe symptoms. First symptoms are usually seen from mid-May as yellow interveinal stripes bordered by brown necrotic stripes on leaves of mature plants. Severely infected shoots die prematurely, usually after heading but before grain filling. The appearance of the resulting "whiteheads" may well be confused with take-all symptoms. Most winter cereals and several grasses are susceptible, but symptoms are less distinct and may well pass undiagnosed. As the pathogen is present and persists in straw, the current U.K. practice of straw chopping prior to incorporation is likely not only to maintain inoculum levels in infected fields, but also to increase distribution of the pathogen within fields, thereby increasing risk.

Prior to the ban on straw burning in the U.K., wheat leaf stripe was considered a disease of minor importance in the U.K. due mainly to deep incorporation of burned straw residues by plowing and conventional drilling. More recently, following the straw-burning ban, however, damaging levels of disease have occurred in fields where straw had been incorporated by plowing to varying depths for at least 4 years, or where crops had been direct-drilled into standing stubble or chopped surface straw residues[2] (Table 7.3). Research studies in long-term straw-disposal experiments have shown that leaf stripe incidence and severity were greatest in plots direct-drilled into standing stubble or chopped straw and less where stubble and straw had been deeply incorporated. Furthermore, in the following wheat crop sown in mid-September, root infection was confirmed in 9% of plants by late November, irrespective of straw-disposal/

cultivation method.[8] Thus, the incorporation of diseased straw by various cultivation practices may, over time, increase the importance of this disease. The fungus may also produce superficial sporodochia on wheat straw, where it survives saprophytically to produce numerous conidia. At this stage the pathogen is known as *Hymenula cerealis.*

Wheat leaf stripe control strategies involve reducing the soil-borne inoculum by alternating spring- and winter-sown crops, maintaining a grass-weed-free soil and a less cereal-dominated crop rotation to decrease disease risk. However, as the pathogen is more prevalent on crop debris that remains on or near the soil surface, deep plowing of infected residues is considered the most effective control strategy, but this conflicts with soil-conservation practices for environmental protection.

7.2.3 Wheat Tan Spot (*Pyrenophora tritici-repentis*)

The tan spot pathogen survives between crops saprophytically as mycelium in the previous year's infected straw. During the post-harvest period and in autumn, perithecia initials form on straw that remains on the soil surface, and these reach maturity the following spring when ascospores are released to initiate infections. If straw is incorporated or buried by deep plowing, the development of these fruiting bodies is much reduced, or even prevented, due to activity of antagonists present in the soil microflora.[13,14] Conversely, the greater the amount of infected straw that remains on the soil surface from year to year, the greater the infection potential. Wheat tan spot could, therefore, be considered an iatrogenic disease, as it was of minor significance in major wheat-growing areas of the world until the ban on straw burning, accompanied by a move to reduced tillage, created severe epidemics during the past two decades.

7.2.4 Wheat Leaf Blotch/Glume Blotch (*Septoria tritici/S. nodorum*)

The principal trash-borne diseases affecting leaves of wheat crops in the U.K. are usually those caused by *Septoria* spp. While *Septoria nodorum* may be seed-borne, primary infection by both species largely arises from ingress by distant transport of airborne ascospores released from standing stubble or leaf and straw debris from previously infected crops. By and large, disease incidence is greater and frequently more severe in crops during the autumn, where chopped straw and stubble are incorporated by tine cultivation, as compared with plow-based systems.

Although surface crop debris is an effective inoculum source, sufficient amounts remain in plowed fields to initiate infection; thus, responses to cultivation are usually short-lived such that by spring there are no consistently significant effects of straw or cultivation treatments on these diseases.

7.3 FOLIAR PATHOGENS OF BARLEY

Although powdery mildew and rusts are frequently prevalent on winter barley crops in the U.K., cultivation practices may indirectly affect disease incidence, as the main source of infection is by airborne conidia released from barley volunteers known as "the green bridge. Thus, cultivation systems that encourage volunteer barley growth increase risk.

The principal trash-borne diseases affecting leaves of winter barley crops in the U.K. are leaf blotch (*Rhynchosporium secalis)* and net blotch (*Pyrenophora teres)*. While both diseases may also be seed-borne, autumn infection arises largely from splash-borne inoculum released from leaf and straw debris from previously infected crops. Volumetric spore traps have been used by the authors to intercept airborne inoculum above both winter wheat and winter barley crops established using different cultivation systems. Although greater amounts of powdery mildew conidia were caught above plowed areas 1 month after sowing than above those established with noninversion tillage or direct drilling, there were no consistent effects with other obligate pathogens such as rusts. As a consequence, disease incidence was most severe in plowed plots, less in those established with noninversion tillage, and least in direct-drilled plots. This response was explained, in part, by differences in plant habit. Foliage of plants established following plowing was more erect in autumn compared to the more prostrate habit in minimum-tillage systems, thereby acting as more efficient receptors of airborne inoculum. However, by early spring over all experiments and years, disease incidence and severity were similar, irrespective of the method of cultivation for crop establishment or whether straw was chopped, incorporated, or burned.

In successive winter barley crops, however, studies on the effect of plowing or direct drilling with three methods of straw disposal (burn, bale and remove, or chop *in situ*) on infection frequency and severity of net blotch (*Pyrenophora teres*) revealed that prior to cultivation only straw burning significantly reduced inoculum potential. Thereafter, where plowing had effectively buried surface residues, irrespective of the method of straw disposal, no conidia were caught for at least three weeks and subsequently were substantially less than in direct-drilled crops[7] (Table 7.4). All direct-drilled barley plants were infected within 27 d of sowing, whereas 42 d had elapsed before all plants sown in plowed areas were diseased (Table 7.5).

In summary, therefore, no consistent effects, outbreaks or unforeseen disease problems, or increases in any foliar disease of winter barley could be directly attributed to the cultivation/straw-disposal practices adopted in these studies.

Table 7.4 Effects of Straw Disposal and Cultivation Method on Inoculum of *Pyrenophora teres*

		Inoculum (Conidia/m^3 × 10^{-4}) 20 cm Above Ground				
				Post Emergence		
Straw Disposal	**Cultivation**	**Precultivation**	**Preemergence**	**2 Weeks**	**1 Month**	**2 Months**
Burned	Plow		0	0.1	0.6	4.6
	Direct drill	440	3.7	87.5	188.9	160.1
Baled	Plow		0	0.2	0.3	3.2
	Direct drill	6443	5.5	59.0	69.8	78.1
Chopped	Plow		0	0.2	0.3	3.1
	Direct drill	3820	2.5	23.1	11.6	9.3

Source: From Jordan and Allen, 1984. With permission.

Table 7.5 Effects of Straw Disposal and Cultivation Method on Incidence of Barley Net Blotch in Autumn

Straw Disposal	Cultivation	18 d I	18 d L	25 d I	25 d L	33 d I	33 d L	52 d I	52 d D
		Incidence (I %), Lesion Number (L) per Leaf and Diseased Area (D%)–Days after Sowing							
Burned	Plow	8	0.05	25	0.20	75	0.75	100	3
	Direct drill	98	2.95	100	4.50	100	4.35	100	93
Baled	Plow	15	0.15	55	0.70	73	0.85	100	4
	Direct drill	98	5.10	100	6.60	100	5.85	100	100
Chopped	Plow	25	0.25	73	1.05	98	2.0	100	3
	Direct drill	100	3.5	100	5.25	100	5.25	100	100

Source: From Jordan and Allen, 1984. With permission.

7.4 SOIL-BORNE PATHOGENS

In addition to pathogens that survive in crop residues on or in the soil surface, soil-borne root-infecting pathogens are also markedly influenced by soil-cultivation methods, surviving either as long-lived resting spores or saprophytically in the soil.

7.4.1 Take-all (*Gaumannomyces graminis*)

This pathogen survives as mycelium in host residues and is mainly confined to the roots and basal stem tissues, from where it grows and makes contact with wheat seedling roots. The hyphae enter the roots directly, with symptoms initially appearing as small black lesions, which may extend along the root length, resulting in root rot. If infection is severe, the whole plant may eventually die. Take–all symptoms (“white-heads”) in one year’s crop does not indicate the risk to severe disease in the following wheat crop because the amount of soil-borne inoculum and the prevailing weather—warm autumn temperatures—determines risk to the following crop. The pathogen is a poor saprophyte and survives in root residues that largely decompose. The time available for root residues to decompose before a new crop is sown has a marked influence on infection potential; thus, delayed sowing may decrease risk. However, most post-harvest inoculum is present near the soil surface; therefore, complete inversion by plowing not only delays contact with roots, but it may also enhance microbial degradation of straw residues, thereby limiting pathogen survival.

Soil-conservation and no-till cultivation techniques might also be expected to differentially affect the incidence of take-all by altering the distribution of inoculum. Nondegraded infected debris that remains on or near the soil surface where the seed is sown, or in the rooting zone just below the soil surface enhances the probability of root infection. Thus, take-all might be expected to be more severe after direct drilling or noninversion tillage. However, measurement of take-all incidence and severity ratings in continuous winter wheat experiments in three agroclimatically different regions of the U.K. that compared plowing with noninversion-tillage and direct-drill systems on three contrasting soil types showed somewhat conflicting results. While take-all incidence was greatest in direct-drilled plots and least in plowed plots 1 month after sowing in October, by mid-February these differences were less evident

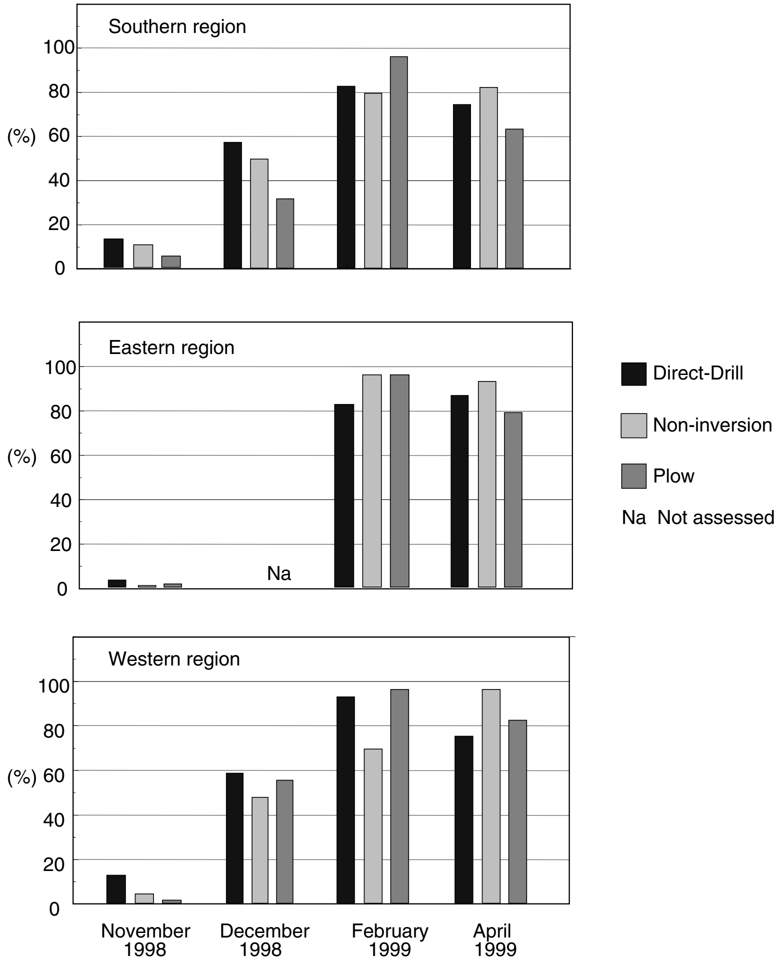

Figure 7.2 Incidence of take-all on roots.

(Figure 7.2). Furthermore, measurements done in spring showed that infectivity of crop debris in the top 10 cm soil declined more rapidly in nonplowed soil than in plowed soil, presumably reflecting the greater activity of antagonistic microflora.

7.4.2 Sharp Eyespot (*Rhizoctonia cerealis*)

Sharp eyespot is a common disease of cereals in the temperate regions of the world, but severely infected crops are rare, and economically damaging levels occur sporadically, when the disease directly weakens the stem. Plants may be attacked at any stage of growth, and early infections can result in pre- and post-emergence plant death in seedlings, stunting, and reduced tillering, resulting in crop thinning. By contrast, late infections appear to have a limited effect.

Rhizoctonia cerealis is a typical soil-borne pathogen whose persistence is aided by its wide host range. Young seedlings are infected by direct penetration of leaf

sheaths from hyphae growing through the soil, which is then carried up the plant through successive leaf sheaths as the stem extends. Dry autumns and light soils allow more extensive hyphal growth, thereby increasing infection opportunities, whereas wet autumns and waterlogged soils induce lysis of hyphae, thereby reducing soil colonization and infection. This could, in part, explain the greater incidence of sharp eyespot in plowed soil than in less disturbed soil where, following plowing for crop establishment, the upper soil layers have a lower soil moisture content and better initial aeration more favorable for hyphal growth.

7.4.3 Foot Rot/Ear Blight (*Fusarium* spp.)

Four Fusarium species commonly attack winter wheat in the U.K. (*Fusarium avanaceum, F. culmorum, F. graminearum,* and *F. nivale)*. These species invade roots, stem bases, and ears and can cause substantial losses in yield and grain quality in some years. All species can be seed- and soil-borne and can survive in straw, soil organic matter, and plant debris. Infection may arise directly from seed- or soil-borne hyphae or from ascospores and conidia produced and released from diseased tissue, which are spread to upper plant parts by wind or rain splash. However, there is limited evidence to demonstrate the contribution of these various inoculum sources to disease aetiology, thereby adding to the difficulty in attributing effects and responses directly to differences in cultivation systems or other agronomic component practices. Nevertheless, long-term (9-year) comparative experiments[5] indicate that, while the prevalence of *Fusarium* spp. is known to increase by incorporation of infected straw, stem-base disease incidence in winter wheat was consistently lower in noninversion-tilled soils than in plowed soils (Figure 7.3).

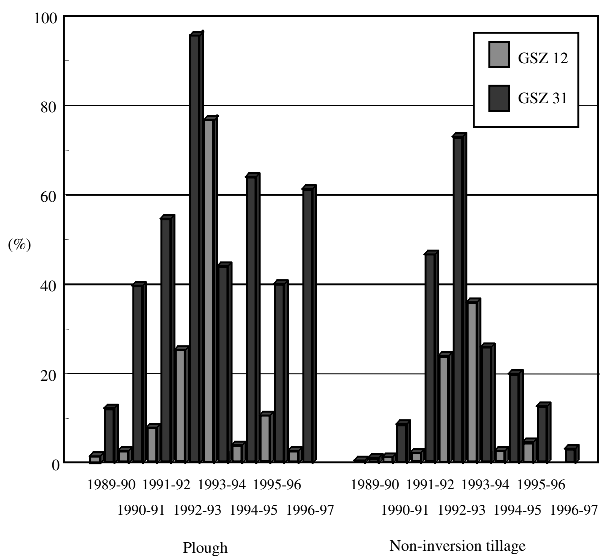

Figure 7.3 Fusarium incidence in plowed and noninversion-tillage systems at GSZ 12 and GSZ 31.

7.5 BARLEY YELLOW DWARF VIRUS

Barley yellow dwarf virus is the most important virus disease of cereals in the U.K. and is most damaging at early stages of crop growth. Transmission is by autumn migration of winged aphids bringing the virus from grasses and other cereals into crops. In most years, infectious individuals are present before the end of September; thus, early sowing is likely to increase the need for pest-control measures, whereas those sown later, in October, are at less risk.

Research on the interactions between straw disposal, cultivation methods, and pesticide use are also suggesting ways of improving the integrated control of this disease that will both reduce costs and protect wildlife. For example, in a year with particularly high risk of barley yellow dwarf virus (BYDV) infection in southwest England, winter barley established by direct drilling or by noninversion tillage showed substantially lower levels of BYDV infection than barley sown after plowing[11] (Table 7.6). Two mechanisms are thought to be involved. First, fewer winged aphids settle on nonplowed crops because the presence of surface residues reduces the contrast between young seedlings and the soil background, which is known to be important for aphid recognition of host plants. And second, larger numbers of polyphagous predators (Carabidae, Staphylinidae and Linyphiid spiders) are present in nonplowed fields in autumn (Tables 7.7 and 7.8), reducing aphid survival and the secondary spread of the virus at the critical early phase of crop establishment.

Table 7.6 Effects of Tillage Practices on Barley Yellow Dwarf Virus

Straw Disposal	Cultivation	BYDV[a]	BYDV(%)	Yield(t/ha)
Bale	Plow	49.2	57.3	2.19
Bale	Noninversion	29.5	24.3	4.17
Bale	Direct Drill	9.5	2.7	5.10
Incorporate	Plow	41.0	42.0	3.25
Incorporate	Noninversion	17.0	8.6	4.39
LSD(p = 0.05)		8.3		0.57

[a] Angular transformed percentages.

Source: From Kendall, D. A. et al., 1991. With permission.

Table 7.7 Effects of Tillage Practices on Carabid and Staphylinid Beetles Caught Each Month in Pitfall Traps

Treatment		Square Root Number/Trap–Day/Month					
Straw Disposal	Cultivation	Oct	Nov	Jan	Feb	Mar	Apr
Bale	Plow	2.11	0.84	1.85	1.29	1.34	1.78
Bale	Noninversion	2.38	1.21	2.46	1.09	1.02	1.15
Bale	Direct drill	3.43	1.06	2.84	0.98	1.08	1.48
Incorporate	Plow	2.27	0.77	1.69	1.27	1.40	1.34
Incorporate	Noninversion	2.59	1.42	2.41	0.94	1.21	1.12
LSD(p = 0.05)			0.75				

Source: From Kendall, D. A. et al., 1991. With permission.

Table 7.8 Effects of Tillage Practices on Linyphiid Spiders Caught Each Month in Pitfall Traps

Treatment		Square Root Number/Trap–Day/Month					
Straw Disposal	Cultivation	Oct	Nov	Jan	Feb	Mar	Apr
Bale	Plow	2.17	1.19	4.35	3.74	4.48	2.70
Bale	Noninversion	2.94	1.10	4.19	3.40	3.93	2.11
Bale	Direct drill	4.63	2.06	3.41	3.18	3.62	1.57
Incorporate	Plow	2.20	0.52	4.47	3.26	4.23	2.25
Incorporate	Noninversion	3.30	1.25	3.81	3.32	4.14	2.12
LSD(p = 0.05)				0.69			

Source: From Kendall, D. A. et al., 1991. With permission.

7.6 DISEASE MANAGEMENT

Soil-conservation/reduced-tillage systems result in increased amounts of crop residues on the soil surface. While this may in cereal monoculture increase the potential for disease carryover from crop to crop, these effects may be much reduced in more balanced cropping sequences and rotations that include a more diverse range of crop species through differences in host specificity of pathogens.[1] Farmers that adopt reduced-tillage systems minimize the risk from disease by more careful management of crop residues during the intercrop period, alternating cereals with broad-leaved crops together with other husbandry techniques such as more precise seed placement and delayed drilling. For example, in arable systems that grow only "first wheats" and optimize the use of profitable break crops, winter oilseed rape was direct-drilled after winter wheat. This allowed the eyespot pathogen to discharge spores onto the nonhost (oilseed rape), thereby exhausting the inoculum supply and eliminating the risk of eyespot in the following wheat crop. In a similar cropping sequence that relied on the plow for crop establishment, eyespot-infected straws were deeply incorporated prior to sowing oilseed rape, then returned to the surface by plowing to establish the following wheat crop, and were still capable of producing spores to infect the "first wheat," thereby increasing risk.

7.7 PATHOGENS OF OILSEED RAPE

7.7.1 Downy Mildew (*Peronospora parasitica*)

In many European countries, downy mildew is considered a major disease of oilseed rape. Severe attacks occur in certain years, especially in autumn, and infection may continue through spring until flowering when climatic conditions are cool and moist. Symptoms of downy mildew appear as ill-defined, irregular areas on young and old leaves, with lower leaf surfaces covered by white or gray mycelium. Severe attacks, often as a consequence of lesions coalescing, can cause premature leaf death. Infected pods may show light brown lesions or may be covered with sparse gray or white sporulating mycelium. Severe attacks of pods can cause premature ripening.

The pathogen survives either as oospores in decaying debris from previously infected crops or as conidia on the lower surfaces of oilseed rape volunteers. Primary infections are favored by moist periods (rain, dew) with temperatures above 10°C. Secondary infections occur through the production and dissemination of conidia by either wind or rain splash. Crop hygiene plays an important role in reducing the incidence of this disease.

While minimum tillage/no-till is frequently used to establish oilseed rape in autumn and surface crop debris is a potential infection source, there have been few reports to show that different cultivation practices influence primary infection or spread.

7.7.2 Stem Canker (*Phoma lingam/Leptosphaeria maculans*)

Symptoms of stem canker, more commonly known as blackleg, first appear in autumn as light brown spots on leaves, frequently with chlorotic/yellow margins. The asexual fruiting bodies (pycnidia) can often be seen in the center of these lesions. Severe autumn infections often lead to premature leaf death. Occasionally, small black lesions occur on the stem bases in autumn that can enlarge in spring and may result in complete stem girdling and a dry rot appearance. Infections on higher parts of the stem may be seen as light brown lesions with a dark brown margin; often, lesions may be slightly sunken. Similar lesions may occur on pods. Autumn infection may arise from both ascospores (*L. maculans)* or from pycnospores (*P. lingam)* released during warm, moist weather from infected plant debris to infect emerging seedlings and young plants.

Where early and deep plowing cultivations are used for crop establishment, pycnospore infection is considered to be the main inoculum source. Where minimum- and soil-conservation-tillage techniques are used, on the other hand, primary infection arises mainly from the sexual ascospore phase. Pycnospores are released during harvest and dispersed by wind to adjacent fields where infection of leaves of emerging seedlings or rape volunteers can occur. Both ascospores and pycnospores can remain viable for some time (2–4 years) within pseudothecia and pycnidia, respectively.

Table 7.9 Major Fungal Diseases of Oilseed Rape

Disease	Causal Organism	Infection Source	Tissue Affected
Downy mildew	*Peronospora parasitica*	Crop debris, volunteers	Leaves, pods
Stem canker	*Phoma lingam; Leptosphaeria maculans*	Crop debris	Leaves, stems
Stem rot	*Sclerotinia sclerotiorum*	Sclerotia in soil	Stem
Dark leaf spot	*Alternaria brassicae*	Crop debris, seed-borne	Leaves, stems, pods
Light leaf spot	*Cylindrosporium concentricum; Pyrenopeziza brasssicae*	Crop debris, seed-borne	Leaves, buds, stems
White leaf spot	*Mycosphaerella capsellae*	Crop debris	Leaves, stems, pods

Many agronomists and pathologists believe that, while different cultivation practices affect the surface distribution and survival of infected crop debris, such practices are unlikely to have a major impact on primary infection if oilseed rape crops are grown as part of a rotational cropping sequence. However, the longevity of inoculum sources may influence infection potential if oilseed rape crops are grown in short rotations (less than 3 years).

7.7.3 Stem Rot (*Sclerotinia sclerotiorum*)

Sclerotinia is common wherever oilseed rape is grown and can cause substantial yield losses. The pathogen has a wide host range; both cultivated and wild species of many families are susceptible including many common weeds found in arable crop fields (e.g., mayweed, cleavers, and deadnettle). Stem rot symptoms can usually be found post-flowering, when lesions appear on main stems and lateral branches as white or gray lesions. Infected plants ripen prematurely and appear as patches of "whiteheads" in oilseed rape fields or die. Infected stems are filled with white mycelium and irregular-shaped black sclerotia. The sclerotia often fall onto the soil during harvest or may remain embodied within oilseed rape stem cavities as surface trash after harvest. These sclerotia, whether within plant tissue or not, remain viable for 7 to 10 years. Sclerotia germination is more frequent and synchronous in the topmost soil horizons from which small light brown apothecia are produced and emerge above soil level. Ascospores are liberated from these apothecia and spread considerable distances by wind to leaves, stems, and flowers of oilseed rape. Fallen infected petals usually act as the initial source of contamination by providing a nutrient source for germination. Warm temperatures, high humidity, and adequate soil moisture in spring promote germination of sclerotia, and apothecia are frequently observed during April and early May in the U.K. in cultivated fields where oilseed rape had been grown the year previously.

Studies within the IACR Long Ashton Less Intensive Farming and Environment (LIFE) Project,[9] in which whole field units (ca. 1 ha) had been either continuously plowed or soil conservation tilled since 1989 (12 years), provided comparative tillage data on a range of arable crop diseases. In the LIFE Project, three fully-phased, seven-course rotational systems were compared—a conventional plow-based system and two integrated systems reliant upon soil-conservation tillage for crop establishment. In each rotation, oilseed rape crops were grown once in 7 years, but as the project was fully phased, an oilseed rape crop was established in each system annually. As winter wheat followed oilseed rape in each rotation, studies were done on differences in apothecia emergence in these crops. Counts (apothecia/m^2) taken annually in spring (April/May) showed that more apothecia emerged from soil in noninversion-tilled wheat fields following oilseed rape (31.5 apothecia/m^2) than in adjacent fields of winter wheat after oilseed rape crops that were established following the traditional plow (5.72 apothecia/m^2). While these differences were marked (a sixfold difference), sufficient ascospores were liberated from both cultivation systems and dispersed at distances to infect rape crops within a 10-km radius. Thus, although cultivation practices have a marked effect on the inoculum potential of Sclerotinia, the authors consider this unlikely to increase disease risk or to have

a localized effect on primary infection because oilseed rape is more frequently grown as a break crop within an arable crop rotation.

7.7.4 Dark Leaf Spot (*Alternaria brassicae*)

Dark leaf spot of oilseed rape is regarded as one of the major diseases of this crop, affecting both leaves and pods, but its incidence and severity of attack are very much climatically driven, being much dependent on warm humid weather. If infection is severe, substantial yield losses can occur, and seed is likely to be infected.

Infection in autumn, whether seed-borne or from other sources, is expressed initially as small brown/black circular spots on leaves, with chlorotic margins, but later lesions become larger with characteristic light and dark brown concentric zones. Older leaves have larger lesions with alternating dark and light brown areas. Main stems and laterals may also exhibit light gray flecks, and affected pods are covered with small black circular areas.

While the pathogen may be seed-borne, it also survives on infected plant debris lying on or within the soil surface layers. Primary infection usually occurs from conidia produced on decaying crop debris and stubble, and infection may occur throughout autumn, spring, and summer on leaves, stems, and pods.

As Alternaria leaf spot is both seed- and trash-borne, the latter being much dependent on prevailing weather during autumn for sporulation and initial infection, the sporadic incidence of this disease in the mild, wet climate of southern England and, hence, the limited comparative tillage date gained by the authors suggest that cultivation practices are unlikely to contribute to greater risk of this disease.

7.7.5 Light Leaf Spot (*Cylindrosporium concentricum/Pyrenopeziza brassicae*)

Light leaf spot of oilseed rape is considered a major yield-limiting disease, especially in U.K., France, and northern Europe. Symptoms are usually seen from late autumn onwards as small white spots or patches on either surface of leaves. During early spring, lesions coalesce and become light brown with a white sporulating fringe. If severe, leaf distortion occurs but not premature leaf fall. Infection of pods can also occur resulting in stunted, distorted, and malformed pods, premature ripening, and pod shatter.

The pathogen survives on crop debris. From this main source of infection, conidia are produced from acervuli and dispersed by wind and rain during autumn to infect young plants and new leaves. The perfect stage is known to occur with ascospores being produced from apothecia on crop debris from late spring until early autumn: ascospores are usually released following rainfall but are dispersed by wind. However, this infection source is considered of minor importance in the life cycle of the disease.

As different cultivation practices distribute and leave various amounts of crop debris in or on the soil from one year to the next, they are likely to have an influence on the infection potential of pathogens that survive on or in crop debris. However,

the authors have no data to support either this hypothesis or the notion that different tillage practices influence primary infection frequency.

7.7.6 White Leaf Spot (*Mycosphaerella capsellae*)

This disease has been reported as potentially damaging in a few regions of U.K. and Europe but is very sporadic in occurrence. First symptoms are usually small yellow or brown lesions on leaves that enlarge and have a white or gray center and dark brown margin.

Primary infection by this pathogen is thought to arise from airborne ascospores produced and released from pseudothecia in infected crop debris. Autumn infection can also occur by conidia produced from thick-walled dark mycelia stromata on crop debris. These stromata can remain viable for 6 to 9 months. Subsequent spread of this disease during spring and summer is by conidia from diseased tissue.

Again, due to the regional and occasional occurrence of this disease in the U.K., there is insufficient information on the effects of various tillage practices on this disease.

7.8 PATHOGENS OF MAIZE

7.8.1 Grey Leaf Spot (*Cercospora zeae-maydis*)

Grey leaf spot is increasingly recognized as one of the most serious, yield-limiting diseases of maize production throughout the world, with its geographic distribution increasing each year.

It has been considered an iatrogenic disease by some American scientists as its proliferation and change from minor pathogen to one of major significance has been attributed to increased use of reduced tillage.

Symptoms first appear as green black water-soaked lesions with chlorotic margins on lower leaves; these circular areas later expand into oval and parallel rectangular brown or tan lesions. Infection is favored by warm, wet, humid weather, and, if severe, coalescing lesions can cause leaf blight or premature leaf death.

The pathogen survives the intercrop period within infected crop residues (leaves), and following moist periods with high humidity in spring conidia are produced on the residues and air-dispersed to infect new plantings. Researchers have clearly demonstrated not only that minimum-tillage practices, which leave much infective crop residues on or in the soil surface, favor infection potential, but also that risk appears to be directly correlated with the amount of surface crop residue. Nevertheless, although complete residue inversion by deep plowing will reduce the initial intrafield inoculum level, the amount and airborne distance distribution of inoculum is such that infection capability is on a regional scale. Furthermore, it is considered by some that the nutrient and soil moisture retention and conservation benefits from reduced-tillage systems provide yield improvements that offset disease-induced damage. This disease can be managed successfully by at least a 2-year break (longer crop rotations) combined with plowing under of infected residues, provided this is done on a scale sufficient to minimize inoculum transfer from field to field.

7.8.2 Anthracnose Leaf Blight (*Colletotrichum graminicola*)

Anthracnose is a disease of worldwide importance, affecting all parts of the maize plant and causing both leaf blight and stem rot. Symptoms appear as small, oval to elongated soaked lesions that turn into brown spindle-shaped spots with yellowish purple margins. Lesions may coalesce and kill entire leaves. Older lesions have a gray center in which small black acervuli can be frequently observed. Following much leaf blight infection, airborne inoculum transfer can also induce a stem/stalk rot, which unlike other stalk rots infection occurs above ground. Symptoms appear as water-soaked areas on the surface of lower internodes that develop into brown/black linear streaks. Severely infected stems are most likely to lodge. The disease is favored by cool or warm, wet, humid weather and continuous maize growing under reduced-tillage systems.

The disease survives saprophytically on infected maize residues that remain on the soil surface. Hence, the increased use/more widespread adoption of reduced tillage systems and continuous maize production has increased the importance and severity of this disease. However, as the pathogen has a poor competitive ability, burial of these residues in soil may well reduce infection potential. Thus, avoidance of continuous cropping (at least a two-year crop rotation) and deep burial of residues by plowing will reduce disease incidence.

7.8.3 Stem and Ear Rots (*Gibberella zeae/Fusarium graminearum; Diplodia maydis*)

Stem and ear rots in maize are most common in warm temperate regions where persistent wetness occurs. The major source of infection/inoculum appear to be infected crop debris (old stems and ears) from a preceding crop. Inoculum transfer of *G. zeae* is by airborne ascospores and macro conidia; thus, incidence and severity may be localized and sporadic since they are climatically determined. Survival of *D. maydis* also occurs in stem residues on or in the soil. Pycnidia are produced on infected crop debris and conidia released to infect stems and ears. Pycnidial survival is greater on surface soil residues than in buried residues.

Evidence indicates that infection potential is directly related to the amount of infective debris on the soil surface; thus, plowing is considered a desirable method of reducing disease risk. Some studies have examined the effect of rotational plowing and alternating-plowing and reduced-tillage systems. While to some extent these inevitably influence the amount of surface crop residues that remain and lower inoculum potential, none is as effective as annual plowing of crop residues.

7.9 DISCUSSION

The plow has traditionally been used as the primary measure for good arable crop hygiene in that, by complete soil inversion, it buries straw and crop debris, weed seeds, and plant pathogens, thereby decreasing perceived risk. Conversely, the presence of straw residues and plant debris of previously infected crops on or near

the soil surface was believed to enhance the survival and prevalence of soil- and trash-borne pathogens, thereby increasing potential risk.

This may, to some extent, be true for certain pathogens, but the presence of crop residues on or within the topmost soil layers markedly affects the microenvironment that, in turn, influences the type and prevalence of fungal pathogens.[3] Retaining more crop residues on or in the soil surface will create a more moist and cooler topsoil layer than under conventionally plowed soil. This, in turn, will influence the development, or otherwise, of trash- and soil-borne pathogens and may result in different disease capabilities. Furthermore, the lack of physical disturbance will markedly affect microbial populations in soil and, invariably, lead to increases in actinomycetes and bacteria, especially the fluorescent pseudomonads that, in turn, may induce faster microbial degradation of straw and straw-borne inoculum. Thus, practitioners of soil conservation/reduced tillage must pay greater attention to the interactions of the whole cropping system. As some diseases are likely to occur more frequently under reduced-tillage systems, they will also vary among soil types, regions, and countries, and results obtained at the regional level may not necessarily apply to local situations. Experimental evidence indicates that the effects of tillage on cereal diseases vary considerably, with conflicting responses for the same pathogen, and are much smaller than originally feared. Thus, there is little evidence to suggest that reduced-tillage systems increase disease risk *per se* or are an important factor in creating disease-limiting situations.

7.10 SUMMARY

Recently in the U.K., there has been a gradual move from complete soil inversion by the traditional plow towards soil-conservation-tillage systems that leave some crop residues on the soil surface. While these practices help maintain soil fertility, improve soil structure, decrease soil erosion, reduce diffuse pollution (emissions of nutrients and pesticides), and allow savings to be made in work rate and establishment costs, they may also affect crop diseases and their control requirements. The effects of cultivation practices on arable crop diseases are variable and depend largely on the specific disease, how the pathogen behaves between crops, how it reaches and spreads within the growing crop, how it affects the crop, and how its effects on the crop are affected by crop husbandry practices. The sources and prevalence of inoculum, the environmental conditions that permit the onset of an epidemic, and the susceptibility of the host plant are factors that control the incidence and severity of diseases from year to year. Losses vary with the nature of the pathogen, the way it affects normal host processes, the timing and intensity of attack, and other environmental considerations.

Diseases most influenced by cultivation practices are those whose pathogens are either soil-borne, as fungal hyphae, or those that survive on previous crop residues that remain on or near the soil surface and cover a range of diseases that infect roots, stems, leaves, and ears. Accounts will be presented on the biology, epidemiology, and the implications of different tillage practices on transmission and spread of some soil-borne and trash-borne splash-dispersed diseases of arable crops. In cereal crops,

information will be presented for eyespot (*Pseudocercosporella herpotrichoides*), sharp eyespot (*Rhizoctonia cerealis*), take-all (*Gaumannomyces graminis*), wheat leaf stripe (*Cephalosporium graminearum*), and *Fusarium* spp., and on the aphid vectors that transmit barley yellow dwarf virus. In addition, the effects of cultivation methods on foliar diseases that originate from overwintering stubble or from previous crop residues of cereals (e.g., *Septoria* spp., *Pyrenophora tritici-repentis*, *Rhynchosporium secalis,* and *Pyrenophora teres*), oilseed rape (*Peronospora parasitica, Phoma lingam, Sclerotinia sclerotiorum, Alternaria brassicae, Cylindrosporium concentricum,* and *Mycosphaerella capsellae),* and maize (*Bipolaris maydis, Cercospora zeae-maydis, Colletotrichum graminicola,* and the ear disease pathogens) will be discussed where cultivation may or may not lead to increased primary infection potential and increased disease risk.

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